United States Patent [19]

Csicsery et al.

[11] **3,838,673**

[45] **Oct. 1, 1974**

[54] **TWO-STAGE COLD START AND EVAPORATIVE CONTROL SYSTEM AND APPARATUS FOR CARRYING OUT SAME**

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[73] Assignee: **Chevron Research Company**, San Francisco, Calif.

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[21] Appl. No.: **295,029**

[52] **U.S. Cl.** .... **123/187.5 R,** 123/3, 13/123, 123/179 G, 123/180 R

[51] **Int. Cl.** **F02m 1/16,** F02m 27/02

[58] **Field of Search**...123/179 G, 3, 180 R, 187.5 R, 123/119 E, 127, 133

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Assistant Examiner—W. H. Rutledge
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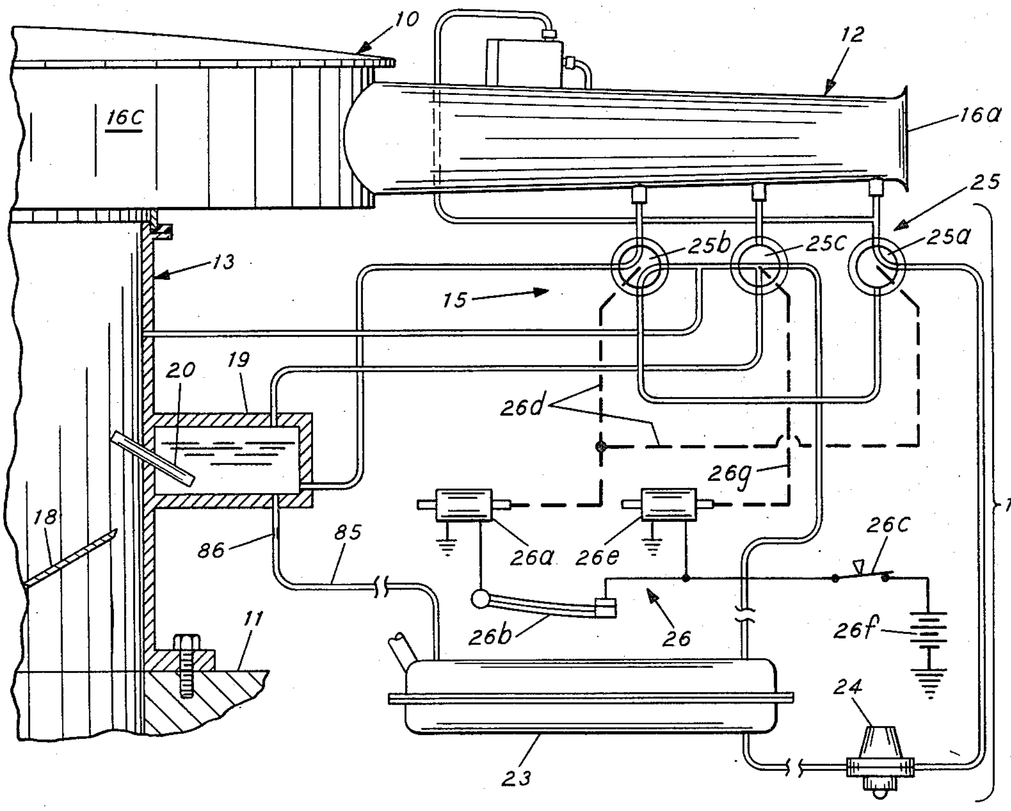
[57] **ABSTRACT**

As cold start is initiated in a spark-ignition internal combustion engine, lower molecular weight constituents of a full-range gasoline are selectively eluted. In accordance with the present invention, the elution system includes a two-stage adsorbent bed of adsorbent material, forming first and second parallel elution zones within a cannister assembly in selective fluid contact with the full range gasoline under control of a valve and conduit network. The first zone terminates in fluid contact with the fuel well of the carburetor of the engine. The second zone terminates adjacent the air filter of the air intake system. The valve and conduit network is fitted with an additional valve metering unit at the second zone to allow only a metered amount of gasoline to enter, say as a function of temperature. A vapor emission control system can also be housed within the cannister assembly and undergo selective operation to prevent escape of vapor emissions originating from within the carburetor and gasoline tank.

10 Claims, 10 Drawing Figures



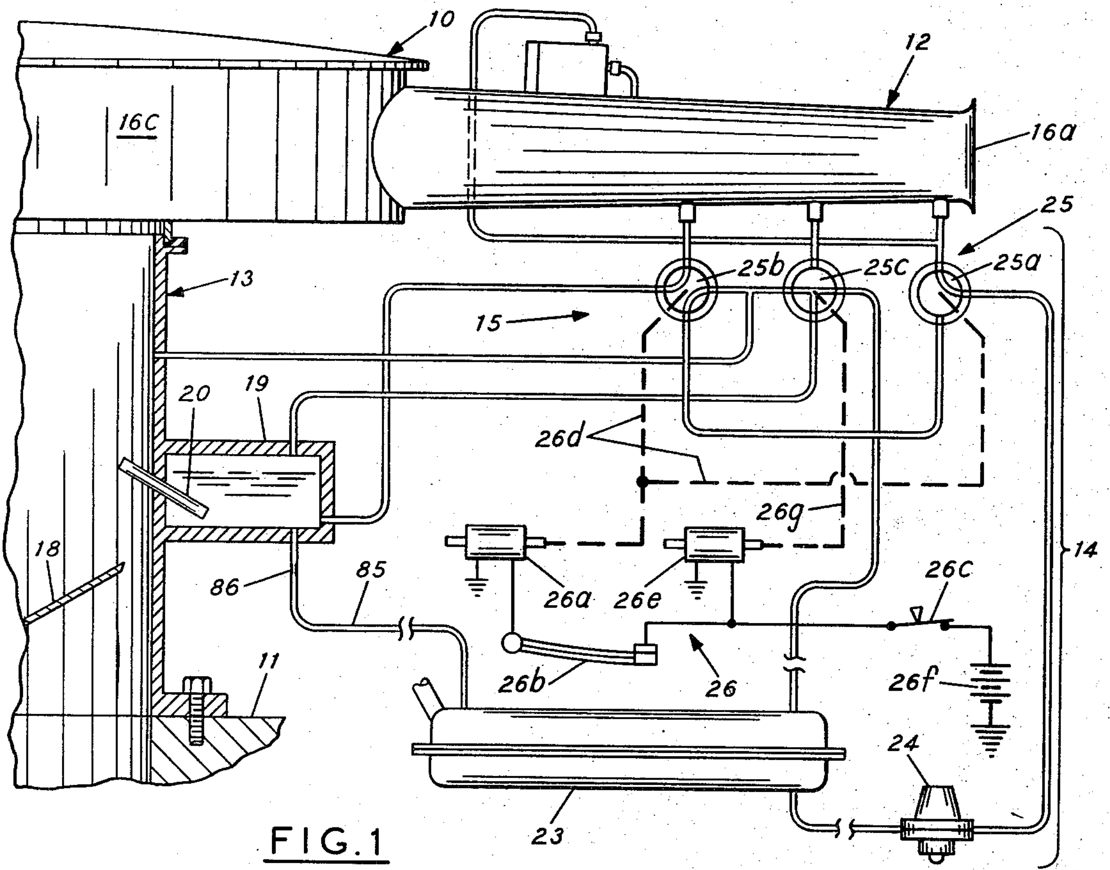


FIG. 1

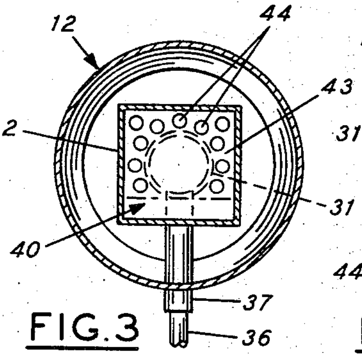


FIG. 3

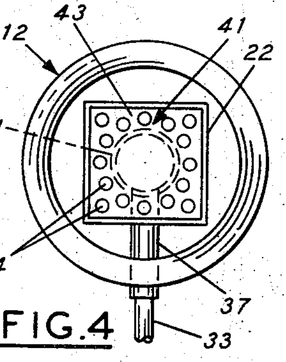


FIG. 4

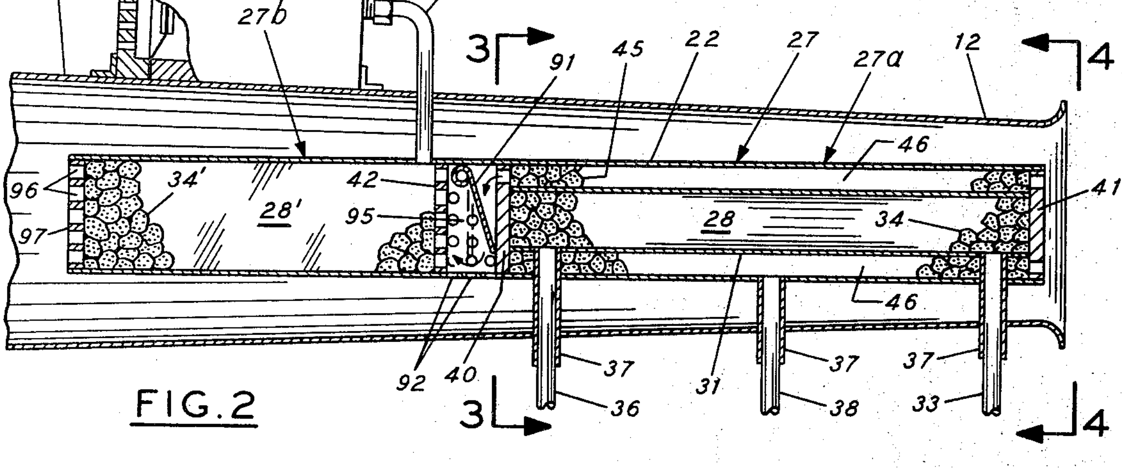


FIG. 2

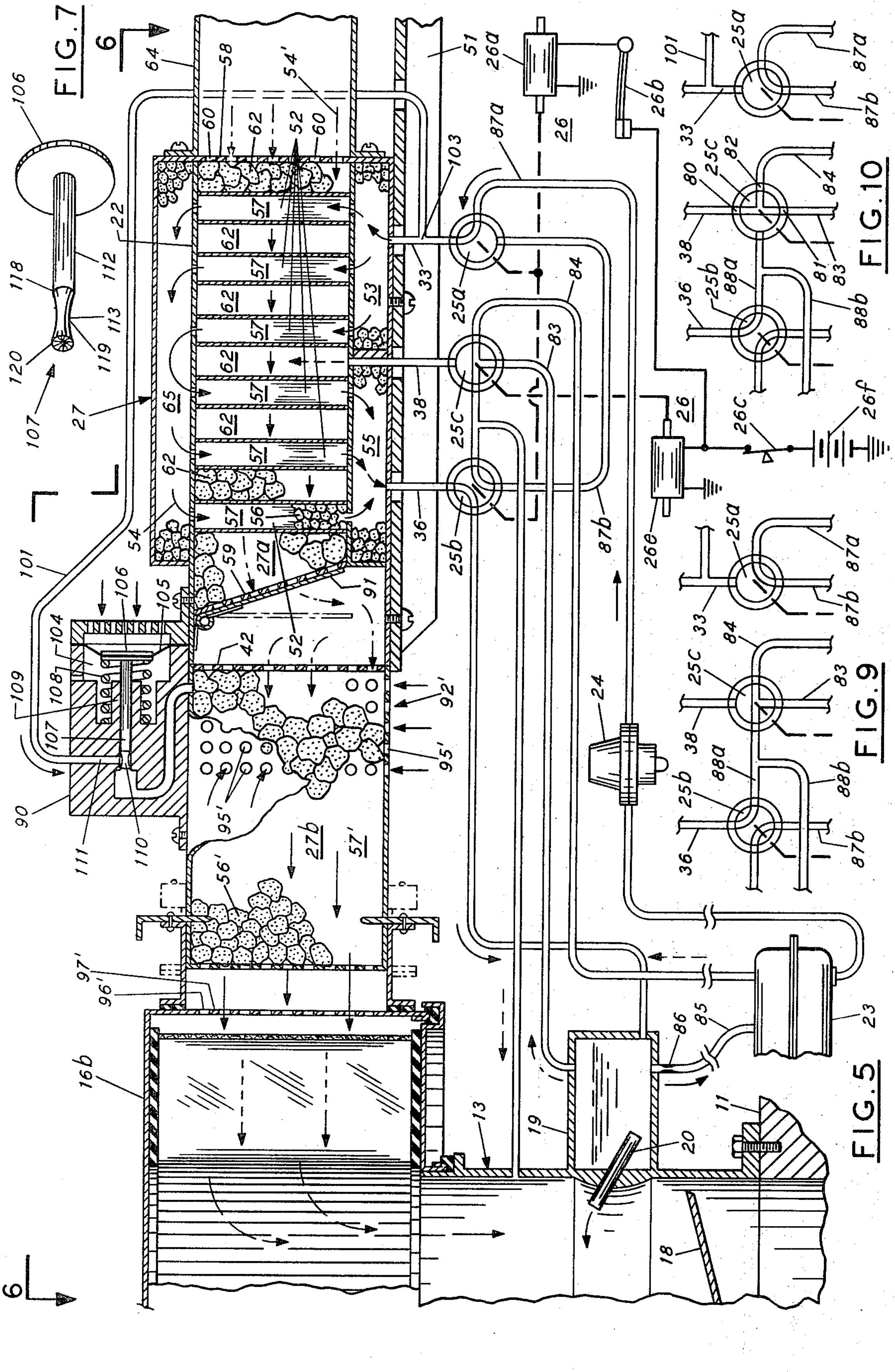


FIG. 7
FIG. 10
FIG. 9
FIG. 5

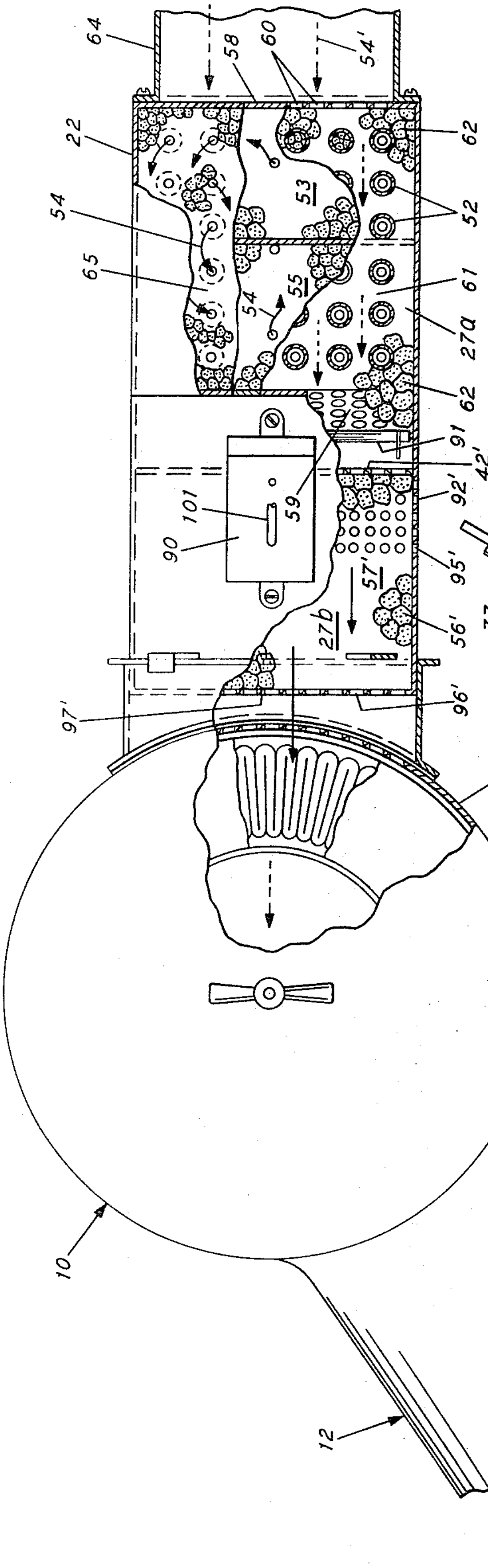

64
58
60
54'
22
54
65
53
55
54
52
62
61
27a
62
59
101
90
91
42'
92'
57'
95'
27b
56'
97'
96'
16b
10
12

FIG. 6

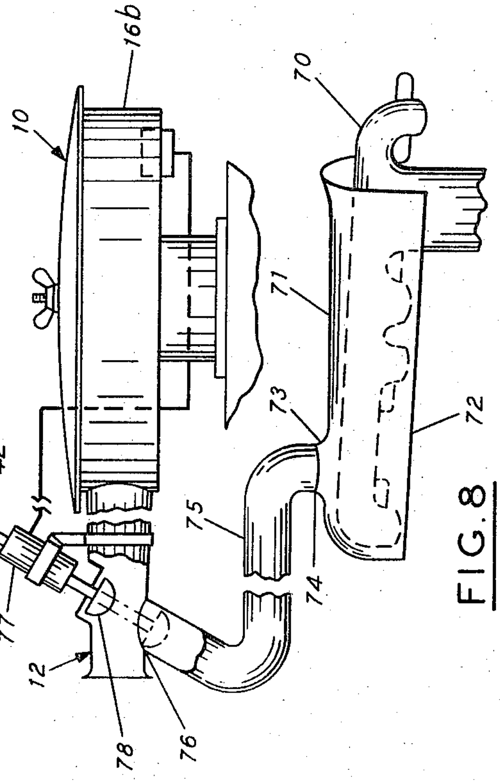

10
16b
70
71
73
72
75
74
77
78
76
12

FIG. 8

TWO-STAGE COLD START AND EVAPORATIVE CONTROL SYSTEM AND APPARATUS FOR CARRYING OUT SAME

RELATED APPLICATIONS

Applications filled simultaneously with the subject disclosure which are assigned to a common assignee and containing common subject matter but claiming distinct inventions, include:

Title	Inventor(s)	Serial No.
Single-Stage Cold Start and Evaporative Control Method and Apparatus for Carrying Out Same	Sigmund M. Csicsery	295,028
Cold Start Method and Apparatus for Carrying Out Same	John F. Senger	295,041
Fuel Injection Cold Start and Evaporative Control Method and Apparatus for Carrying Out Same	Sigmund M. Csicsery	295,040
Two-Stage Fuel Injection Cold Start Method and Apparatus for Carrying Out Same	Sigmund M. Csicsery and Bernard F. Mulaskey	295,030

The present invention relates to cold starting and evaporative emission control of a spark-ignition internal combustion engine and has for an object the provision of a simple and effective cold start and evaporative control system for use in such engine

i. for selectively eluting from a full range fuel flowing to the engine only the lower molecular weight constituents at cold start so as to allow quick starting of the engine without excessive amounts of unburned hydrocarbons appearing at the exhaust as well as

ii. for adsorbing evaporative emissions from the gasoline tank and carburetor bowl when the engine is not operating.

Higher molecular weight constituents adsorbed during cold start and/or light, evaporative emissions adsorbed during the disabled cycle of the engine are purged from the system only after the engine has been warmed and the full range fuel utilized.

During cold start of spark-ignition internal combustion engines, the fuel-air ratio is generated by the air-fuel intake system, say a conventional carburetion system. At cold start, the air-fuel ratio can be varied (enriched) to assure adequate amounts of lower molecular weight constituents of the fuel at the intake manifold. By operation of a plurality of interrelated well-known parts, the higher molecular weight constituents become more easily vaporized to form combustible vapor-fuel/air ratios to allow starting of the engine even at low operating temperatures. However, since remaining higher molecular weight constituents are not oxidized even if the start is rapid, such remaining constituents contribute to the formation of unburned hydrocarbons at the exhaust.

Although a more volatile fuel having a lower boiling point, would permit faster starts and warmup and reduce exhaust pollutants, including unburned hydrocarbons and carbon monoxide emissions, experience shows that full range engine performance using the more volatile fuel would be adversely affected. In this regard, fuel consumption would be greatly increased over all ranges of driveability.

In accordance with the present invention, rather than use a more volatile fuel under a multiplicity of operating conditions of a spark-ignition internal combustion engine (particularly during cold start), lower molecular weight constituents of a full-range gasoline are selectively eluted as cold start is initiated by the driver. The elution system includes a two-stage adsorbent bed of adsorbent material, forming first and second parallel elution zones within a cannister assembly in fluid contact with the full range gasoline. The adsorbent material—usually in pelletized form—with the first elution zone is preferably housed within a tubular means disposed within the cannister assembly, the tubular means being positioned within a much larger shell housing in fluid contact with a valve and conduit network. Entry of the gasoline is initiated by the valve and conduit network under control of a controller circuit.

Within the second elution zone, the valve and conduit network is fitted with an additional valve metering unit in parallel with the first elution zone which allows only a metered amount of gasoline to enter as a function of temperature. A circumferentially extending air entryway of approximately the shell housing dimensions is formed near the rear end of the second elution zone, the nozzle of the valve metering unit terminating adjacent the air entryway. As gasoline enters via the nozzle and mixes with the air, it is quickly carried through the second elution zone as selective retardation of the higher molecular weight compounds occurs. Due to the velocity of the accompanying air as well as the presence of openings within a screen at the remote, exhaust end of the second elution zone, the lighter low molecular weight constituents are caused to be broken into a fine atomized spray. The atomized spray contains both liquid and vapor phases of the lighter constituents, and is readily flowable through the air filter of the air intake system of the engine into the carburetor. At the carburetor, the cold start fuel constituents from both first and second elution zones are mixed together with air to form a highly combustible cold start air-fuel mixture.

Construction of the cannister assembly can vary. Preferably the arrangement within the first elution zone resembles that provided for a shell-and-tube heat exchanger whereby tube-side gasoline—during cold start—passes through the tubular means packed with the adsorbent material (single pass percolation). Within the second elution zone, the construction of the cannister assembly includes a housing integrally contacting the shell housing of the first elution zone, with the aforementioned entryway disposed therebetween. While the absorbent materal therein can be similar to that used in the first elution zone, or may be different, as explained below, it is always retained within the housing. Selective retardation of the high molecular weight compounds, vis-a-vis the lighter components occurs so that, during start up, only the light constituents pass to the carburetor, for later consumption within the combustion chambers of the engine. Since the starting cycle of an internal combustion engine is quite short, say from 1 to 15 seconds and the residence time for the heavier compounds within the elution zone is 1 to 2 orders longer say from 1 to 3 minutes, the latter compounds remain selectively adsorbed with both the first and second parallel elution zones.

Preferably, but not necessarily, the present invention has additional utility in preventing evaporative emissions originating within the fuel well of the carburetor and/or within the gasoline tank from escaping into the atmosphere. In this aspect of the invention, the escape of large amounts of hydrocarbon fumes and vapors into the atmosphere from a spark-ignition internal combustion engine in an inoperative state, is acknowledged as being a serious environmental problem, especially within large cities. In this regard, studies indicate that up to 15 percent by volume of the total vapors admitted into the atmosphere, originate from evaporative emissions from spark-ignition internal combustion engines. Governmental bodies are attempting to satisfy emission regulation in cooperation with industry; for example, California Motor Vehicle Pollution Control Board has proposed the following standards for control of evaporative emissions: 2 grams per hot soak from the carburetor fuel well and 6 grams per day from the fuel tank under standard operating conditions. In this regard, the present invention can be selectively, but no necessarily, operative during such time periods to adsorb such evaporative emissions and prevent their escape into the atmosphere by arranging the first elution zone so as to provide space between the tubular means and the shell housing. Into that space can be inserted an adsorbent material, preferably of the nonpolar type, which form an adsorptive capture zone for use in preventing escape of evaporative emissions into the atmosphere when the engine is in an inoperative state.

The associated valve and conduit network and the controller circuit can place both the elution and capture zones of the cannister assembly in fluid contact with other relevant fuel system components as required; for example, after the engine has started and warmed up both the elution and capture zones can be purged of adosrbed constituents (adsorbates) by passing shell-side gases (either full or partial engine air or manifold exhaust gases) through these zones. Thus, not only is the present invention able to rapidly elute low molecular weight fuel constituents at cold startup, but the other adsorbed fuel components can be automatically desorbed without formation of excessive amounts of pollutants at the exhaust.

Although the prior art has suggested both polar and non-polar adsorbent materials for use in vapor recovery systems, there has been no suggestion of using adsorbent materials in an elution system for selectively eluting from a full-range gasoline, only light, low molecular weight components thereof, to assure a smooth pollution-free start of a spark-ignition internal combustion engine.

Further objects, features and attributes of the present invention will become apparent from a detailed description of several embodiments to be taken in conjunction with the following drawings in which:

DESCRIPTION OF THE FIGURES

FIG. **1** is a schematic view of a portion of an engine fuel system incorporating the present invention illustrating a typical carburetor and air cleaner assembly interconnected between a cold start — evaporative emission system of the present invention, said cold start evaporative control emission system including a cannister assembly housed within the air intake line of the air cleaner assembly under regulation of a valve and conduit networks controlled by a controller circuit;

FIG. **2** is a partial cutaway of the cannister assembly of FIG. **1**;

FIGS. **3** and **4** are section views taken along lines **3—3** and **4—4** of the cannister assembly of FIG. **2**;

FIG. **5** is a schematic view of another embodiment of the present invention illustrating a typical carburetor and air cleaner assembly in which the cannister assembly including first and second parallel elution zones is mounted by means of a platform attached to the fire wall of the engine compartment;

FIG. **6** is a plan view of the cannister assembly and air cleaner assembly of FIG. **5** and illustrates the position of a valve metering unit afixed to an outer housing of the cannister assembly;

FIG. **7** is a fragmentary view of a metering pin of the valve metering unit of FIG. **6**;

FIG. **8** is a partially schematic view illustrating an alternate embodiment by which air can be heated to an elevated temperature to better desorb the cannister assembly of FIGS. **1** and **5**;

FIG. **9** is a fragmentary view of the valve and conduit network of FIGS. **1** and **5** illustrating the position of the valve network after cold start has been achieved and the engine is at running temperature so that the cannister asembly can be desorbed by passing gases in heat transfer contact therewith:

FIG. **10** is yet another fragmentary view of the valve and conduit network of FIGS. **1** and **5** illustrating the position of the valve network when the engine is in an inoperative state.

Referring now to FIG. **1**, there is illustrated an engine fuel system **10** connected to an engine intake manifold **11** of a spark-ignition internal combustion engine (not shown). Fuel system **10** of the present invention includes an air intake system **12**, a carburetor **13**, a fuel intake system **14**, that includes cold start-evaporative control system **15** of the present invention.

To form a combustible air-fuel mixture, air enters by way of air intake system **12**, say by way of air inlet line **16***a*, and is filtered at an air filter interior of an air filter housing **16***c*, before entry into carburetor **13**. Carburetor **13** includes a throttle valve **18**, a fuel well **19**, and a discharge nozzle **20**. Fuel well **19** contains a metered quantity of gasoline to be mixed with air passing discharge nozzle **20** and to be passed through intake manifold **11** into the engine combustion chambers (not shown) where combustion occurs. Supplying fuel well **19** with a metered quantity of gasoline is by means of fuel intake system **14**. Fuel intake system **14** includes a gas tank **23** containing a reservoir of full-range fuel (i.e., a full-boiling gasoline), a fuel pump **24** and cold start-evaporative control system **15** of the present invention. Cold start-evaporative control system **15** includes a valve and conduit network **25** in fluid contact with the discharge side of fuel pump **24** but under operative control of controller circuit **26**. A cannister assembly **27**, see FIG. **2**, mounted adjacent to the air intake system **12**, say within air inlet line **16***a*, is likewise an element of the cold start system **15** as noted below.

It should be noted that carburetor **13** has been modified to exclude from operation a choke valve so that the enrichment of the fuel-air ratio is performed solely by the cold start-evaporative control system **15** of the present invention. Briefly, with reference to FIG. **2**, cannister assembly **27** is seen to include two parallel sections: a forward section resembling a conventional but scaled down tube-and-shell heat exchanger generally indicated at **27***a*, and a rear section **27***b* including a valve metering unit **90.** An elongated valve gate **91** interior of common housing **22** of the sections controls internal air flow between the forward and rear sections **27***a* and **27***b*, while an air entryway **92** of the same dimensions as and integral with the common housing **22** control external air flow into the rear section **27***b* via a swedged ribbon of openings **95.** In the present aspect of the invention, not only can light low molecular weight components (liquid phase) be conveyed to the fuel well **19** of the carburetor **13** through operations of forward section **27***a*, but also an atomized spray of such components (both liquid and vapor phase) can be simultaneously eluted through ports **96** of screen **97** of rear section **27***b*. As is readily apparent, provision of a combination of atomized spray and liquid cold start fuel mixed at the carburetor assures rapid cold start of the engine under a variety of operating conditions without the formation of pollutants at the exhaust.

Valve and conduit network **25** of FIG. **1** is seen to include cold start inlet and exit valves **25***a* and **25***b*, respectively controlled mechanically by relay means **26***a* of controller circuit **26** through transducer **26***d* and electrically through bimetal temperature switch **26***b*, ignition switch **26***c* and battery **26***f*. A second relay **26***e* of controller circuit **26** is seen to control operation of evaporative emissions control valve **25***c* of valve and conduit network **25** through mechanical transducer **26***g*. Transducers **26***d* and **26***g* convert rectilinear travel of the relay means **26***a* and **26***e* to the rotational motion.

COLD-START EVAPORATIVE CONTROL SYSTEM 15.

As indicated with reference to FIG. **1**, during cold start of a spark-ignition internal combustion engine, a full-range fuel, i.e., a full-boiling gasoline, having both low and high molecular weight constituents, is conveyed from gas tank **23** through fuel pump **24** into valve and conduit network **25**, and thence to cannister assembly **27**, (FIG. **2**). Although a full-boiling gasoline enters the cannister assembly **27**, in accordance with present invention, due to selective retardation of heavier components, only lightweight constituents are eluted during cold start. Such selective retardation during the initial one-three minutes of the starting cycle of the internal combustion engine is achieved based on operational characteristics of parallel first and second elution zones **28** and **28′** formed within the cannister assembly **27.** Since the nature of the elution zones **28** and **28′** is based on functional characteristics of adsorbent materials, in general, and of polar and nonpolar type adsorbent materials, in particular, a brief discussion of adsorbtion systems is believed to be in order and is presented below with reference to FIG. **2.**

Essentially, the first and second elution zones **28** and **28′** form parallel columns of parallel frontal analysis chromatagraphs (solution adsorbtion) as classified in accordance with *Kirk-Othmer Encyclopedia of Chemical Technology*, 2nd Ed., Volume 5, page 418. In accordance with *Kirk-Othmer* op. cit., such classification is essentially based on the nature of the mobile phase of the system percolating through an adsorbent material. In the case at hand, within the first elution zone **28** full-boiling gasoline enters by way of inlet conduit **33** and percolates through polar adsorbent material **34** packed within the tubular means **31.** Note at the outlet conduit **36**, the order of elution is a function of the order of polarity of the constituents of the full range gasoline since the individual molecules of the high molecular weight constituents within the tubular means **31** shuffle at a slower rate between the mobile and stationary phases than do the lighter constituents. Within the second elution zone **28′**, the full-boiling gasoline is seen to have parallel simultaneous entry into second elution zone **28′** by way valve metering unit **90.** Adsorbent material **34′** retained within common housing **22**, provides at end wall screen **42** an identical order of eluted products as polar adsorbent **34** with first elution zone **28.** Within the elution zone **28**, separation occurs because of the polarity, nonpolarity groupings of these constituents whereby different relative velocities are imparted to the individual molecules of the groupings. The least strongly adsorb low molecular weight liquid components elute first as a group followed by a second grouping containing say both the low and high constituents and so forth until all constituents have appeared. Within the elution zone **28′**, separation is apparently not, primarily, a function of polar interaction since both polar and non-polar materials can be used to form the adsorbent material **34.**

Residence time of the low molecular weight components within the elution zones **28** and **28′** is a function of many factors including the length of the elution zones as well as the pressure drop during percolation through the adsorbent materials **34** and **34′**, respectively. However, the residence time of the heavier components is much longer within each zone, usually in a range of 1–3 minutes. However, care ought be exercised in this regard. The flow rate of the mobile phase must be slow enough to allow maximum transfer of the molecules of the heavier constituents into and from the stationary and mobile phases. Since selective retardation of the heavier constituents is quite long, say 1–3 minutes, while the typical starting cycle of a modern engine can be quite short, say from 1 second up to 15 seconds (except when problems of starting occurs), the heavier constituents remain adsorbed within the elution zone **28** and **28′** after the engine has started. This proposition assumes of course that the adsorbent material **34** and **34′** are of a compatible polar classification.

CLASSIFICATION OF ADSORBENT MATERIAL 34 AND 34′

As previously mentioned, competition for the high molecular weight groupings of the full-range fuel has been found in the forward elution zone **28** to be dependent on its selective interaction with the adsorptive material **34.** I.e., the degree of interaction (between the material **34** and the more polar heavier constituents of the full-range fuel) has been found to be directly related to the magnitude of polarity of the adsorptive material. In accordance with the present invention adsorptive material **34** should be polar and preferably selected from following non-exclusive listing of popular polar adsorptive materials, with silica gel being somewhat preferred:

Polar Adsorptive Materials	Remarks
Silica gel	
Alumina	Activated Preferred
Barium sulfate	
Calcium carbonate	
Glass	
Resins and plastics	Ion-exchange only
Quartz	
Titanium dioxide	
Metallic oxide	
Zeolites (sieves)	
Sil X	
Solid Support Material Coated with Liquid Adsorbers such as chemically bonded liquids. (E.g. Durapak; solids coated with Octadecyl Silane, Fluoro-ethers, etc.)	Commonly used in Liquid-Liquid Partition Chromatography

In the case of rearward elution zone **28'**, competitions for the higher molecular weight constituents is not so dependent upon polarity of the adsorption material **34'** so that in addition to the above-listed polar materials the following non-polar materials may also be used:

Non-Polar Adsorbent Material	Remarks
Charcoal	
Charcoal blacks	
Graphite	
Resins and plastics	Organic only
Paraffins	
Stibnite	
Sulfides	Metallic only
Talc	

The elution zones **28** and **28'** can be formed of adsorbent material in granular, pellitized or powdered form. Preparation is straight forward: the adsorbent material should be calcined, acid and base washed, neutralized, and size graded prior to insertion within the cannister assembly **27**, say along lines set forth in *Kirk-Othmer op. cit.*, Volume 1 at page 460. Since as previously mentioned, the flow rate of the full range gasoline within the elution zones **28** and **28'** must be slow enough to allow maximum transfer of the molecules of the heavier compounds into and from the stationery and mobile phases, the size of the adsorbent material **34** and **34'** should be such as to minimize the pressure drop across a cannister assembly **27** without adversely affecting its ability to adsorb these constituents. In this regard, an elution zone having about a 1-liter capacity filled with activated alumina of 8 by 14 mesh has been found to adsorb from 200–300 ml. of high molecular weight constituents while yielding about 400 to 500 ml. low molecular weight constituents in the first initial minutes of the cold starting operation. In addition to activated alumina, within the forward zone **28**, it has been found that polar gels, such as silica gel, titania gel, zirconia gel, and alumina gel, Fuller's earth, bentonite, diatomaceous earth, forisil, attupulgus, and any other polar adsorptive materials are also useful in carrying out that aspect of the present invention. However, in some cases, non-polar materials may be substituted without undue loss in effectiveness. In this regard, non-polar materials listed hereinbefore are appropriate.

CANNISTER ASSEMBLY 27.

Construction of the cannister assembly **27** varies with the type of mounting required to attach the cold start-evaporative control system **15** adjacent to air intake system **12.** In FIG. **2,** cannister assembly **27** is seen to include forward and rear sections **27***a* and **27***b* mounted within the intake air line **16***a* of the air intake system **12.** The overall dimensions of the cannister assembly **27** thus must be minimum so as to allow sufficient air to bypass into the carburetor **13.** To accomodate the required volume of adsorbent material constituting the elution zones **28** and **28'** (FIG. **2**), the common housing **22** may have to be correspondingly ultralong. Within the forward section **27***a* support of tubular means **31** can be brought about by welding radial supports **37** to the side wall of air line **16***a* to which cold start conduits **33, 36** as well as evaporative conduit **38** are attached. Within the rear section **27***b*, support of the common housing is by way of inlet conduit **94.** Since the forward and rear sections have essentially individual operational characteristics, each section will now be discussed in sequence.

FORWARD SECTION 27*a*.

Tubular means **31** is seen to be concentric of common shell housing **22** and includes supports **40** and **41** at respective ends thereof. Each support **40** and **41** has peripheral edges in contact with the shell housing **22.** Each support **40, 41** also includes a central plug zone in plugging contact with the central tubular means **31** as well as an intermediate zone **43** (See FIGS. **3** and **4**) including a series of ports **44** in registry with a modified parallelpipedonic spacing existing between tubular means **31** and the shell housing **22** wherein adsorbent material **45** is supported. Adsorbent material **45** located in the aforementioned space constitutes a vapor adsorption zone, generally indicated at **46** (adsorption capture zone). In this aspect of the invention, deactivation of ignition switch **26***c* (of FIG. **1**) deactivates relay **26***e* causing rotation of the vapor control valve **25***c* to the position shown in detail in FIG. **10.** The fuel well **19** and the gas tank **23** of FIGS. **1** and **5** are thus placed in fluid contact with the vapor adsorption zone **46.** Note that at the shell side exterior of the central tubular means **31,** within zone **46,** the atmosphere is permitted to enter at will but is frustrated to exit by operation of valve gate **91.** During cold start, the shell-side air is at about the same temperature as the fluid interior of the tubular means **31,** so little heat is transferred between the two fluids.

REAR SECTION 27*b*.

Note that tubular section **31** of the forward section **27***a* of FIG. **2** does not extend into the rear section **27***b* but terminates well forward of end wall screen **42.** However, the elution zone **28** defined by adsorbent material **34** within the tubular means **31,** is continued in the rear section **27***b*. In more detail within the interior of common housing **22** (preferably of rectangular cross section, see FIGS. **6, 3** and **4**) the rear section **27***b* is provided with adsorbent material **34'** forming the second elution zone **28'**. The adsorbent material **34'** is the preferably of the same polar type as the absorbent material **34** within tubular means **31** of the forward section **27***a*, as previously mentioned but can be different if desired.

Atop the common housing **22** adjacent rear section **27***b*, is the valve metering unit **90**. As previously explained, with reference to FIG. **1**, the valve metering unit **90** has an inlet conduit **94** connected to the elution zone **28'**.

Valve unit **90** also has features best illustrated with reference to FIG. **5**. As indicated, the valve unit **90** includes conduit **101** connected at T-junction **103** to the conduit **33** in series with cold start inlet valve **25***a* of valve and conduit network **25**. Thus when inlet cold start valve **25***a* is positioned as depicted in FIGS. **1** and **5**, not only can full-range fuel enter forward section **27***a* but also such fuel simultaneously enters rear section **27***b* via the T-junction **103**, conduit **101** and valve metering unit **90**.

The amount of full-range fuel metered into the elution zone **57'** by the valve metering unit **90** is a function of air temperature. Now in more detail, the valve metering unit **90** is seen to include a chamber **104** into which is positioned a bimetallic diaphragm **105**. The diaphragm **105** is attached, at its outer edge, to the side walls of the chamber **104** and has a more central location in engagement with enlarged head **106** of a metering pin **107**. The spring force provided by the diaphragm **105** is seen to be in opposite direction to the spring force provided by compressions spring **108**. Compression spring **108** is seen to be mounted about boss **109** at an end wall of the chamber **104**. Boss **109** is also seen to be provided with an opening **110** into which the metering pin **107** is slideably mounted. As temperature changes occur as sensed by bimetallic diaphragm **105**, relative movement of the diaphragm causes corresponding movement of the metering pin **107** relative to the opening **110**.

Intersecting opening **110** at a right angle is passageway **111**. Passageway **111** has an upper inlet port in fluid contact with the conduit **101** and an exit port in fluid contact with metering pin **107**.

FIG. **7** illustrates metering pin **107** in more detail. As indicated, the pin **107** consists of an elongated shank portion **112** tapered at a remote end to form a reduced segment **113**. At the opposite end, the shank portion **112** is seen extending into contact with the enlarged head **106**. Reduced segment **113** is seen to be swedged as a function of length. That is to say, the reduced segment **113** is reduced in diameter from a beginning section **118** to a mid-portion section **119** and then is allowed to increase in diameter until a maximum is reached at end section **120**. Accordingly, the amount of gas which can pass into the elution zone **28'** is dependent upon whether or not minimum section **119** or beginning section **118** is in registry with passageway **111**, i.e., when the pin **107** is as depicted in FIG. **5**.

Referring again to FIG. **5**, as the temperature changes, it is apparent that the changes in pin location of metering pin **107** relative to passageway **111** meters gasoline into elution zone **57'** as a function of temperature. As the gasoline enters the elution zone **57'** in liquid phase, percolation through the elution zone **57'** is initiated. Since the absorbent material **56'** is of the same polar characteristics as the material **34'** within the elution zone **28'** of FIG. **2**, selected retardation of the aromatic constituents likewise occurs. In the manner as previously explained, air entryway **92'** is provided with a swedge band of openings **95'** positioned not to interfere with the operation of valve gate **91**. Vacuum in the intake manifold causes air to flow through the radial openings **95'** and thence through the elution zone **57'** in the accompaniment of the percolating full-range fuel. Due to the velocity of the accompanying air as well as the presence of openings **96'** of screen **97'** causes the eluding paraffinic constituents at the exit of the rear section **27***b* to be broken up into a fine atomized spray (atomized vapor). The atomzied spray consists essentially of low molecular weight constituents both in liquid and vapor phases in the accompaniment of air. The fine atomized spray is then drawn through the air filter **16***b* of the air intake system into the carburetor **13**. Due to the velocity of the accompanying air through the rear section **27***b*, the resulting atomized spray undergoes very little condensation.

It should be noted that during cold start, spring-loaded gate **91** between the forward and rear sections **27***a* and **27***b*, prevents purging of the forward and rear sections **27***a* and **27***b*, prevents purging of the forward section **27***a*. However, as manifold pressure substantially changes indicating full-load operations have begun, the spring loaded gate **91** swings from the position indicated in solid lines in FIGS. **1** and **5** to the positions indicated in phantom line. In that way, engine air (full or partial) can flow through the forward and rear sections **27***a* and **27***b* to allow a purging of adsorbed materials.

In FIG. **5**, the support of the forward and rear sections **27***a* and **27***b* differs markly from that of FIG. **1**. The cannister assembly **27** of FIG. **5** is seen to be mounted by common shell housing **22** to a platform **51** which in turn is attached to a firewall (not shown) of an engine compartment. Additional space afforded by the platform **51** allows for a more complex constructural design of the forward section **27***a*. Instead of constructing tubular means **31** of a single tube as depicted in FIG. **1**, a series of upright tubular means **52** can be provided to carry the gasoline entering inlet chamber **53** along a series of sinusoidal passes through the interior of the forward section **27***a*, such passageways resembling those provided in a conventional tube-and-shell heat exchanger. The series of passes made by the gasoline are indicated by arrows **54** while dotted arrows **54'** indicate the direction of gas phase flow. In the depicted arrangement, tube-side gasoline is conveyed—during cold starting within the forward section—through the tubular members **52** via inlet chamber **53** (multipass percolation) through adsorbent material **56** to intermediate chamber **65** and thence to exhaust chamber **55**. Due to increased total length of the tubular members **52**, resulting elution zone **57** is likewise greatly enlarged over that depicted in FIG. **2**.

The rear section 27b is similar to that depicted in FIG. **1**, and provides the elution zone **57'** comprising adsorbent material **56'** similar to material **34** retained with elution zone **28** of FIG. **2**. Retention of the adsorbent material **56'** in elution zone **57** is seen to be provided by screens **42'** and **97'**.

Further constructural features of the embodiments depicted in FIG. **1** and FIG. **5** are readily apparent. For example, both in FIGS. **1** and **5**, the common shell housing **22**, is seen to be rectangular in cross-section whereby the assembly forms a parallelepipedon. As illustrated in FIG. **6** the shell housing **22** of the forward section **27***a* is also seen to include end walls **58** and **59**. End wall **58** includes a series of ports **60** to allow selective entry of hot, exhaust gases via conduit **64** into an adsorptive vapor capture zone generally indicated at **61** exterior of tubular member means **52** but interior of shell housing **22**. Within the vapor capture zone **61**, adsorbent material **62** is supported. At the opposite end, the common shell housing **22** is also seen to attach by way of fasteners to the air cleaner housing **16***b*. Such attachment is oriented such that the ports **96'** are in fluid registry with holes in the air cleaner housing **16***b*.

Although the embodiment depicted in FIG. **1** utilizes full or partial engine air warmed to a high temperature for this purpose, it should also be noted that embodiment of FIG. **5**, contemplates utilization of gases from the exhaust manifold to purge with the elution and vapor adsorption zones of adsorbed constitutuents.

After the engine has started and warmed, the cold start exhaust and inlet valves **25***a* and **25***b* return to relaxed positions depicted in FIG. **9**, and the fuel intake system switches over to full utilization of the full-range gasoline. That is to say, fuel conveyed from fuel pump **24** passes via conduit **87***a* to inlet valve **25***a* and thence from U-shaped conduit **87***b* and exhaust cold start valve **25***b* to the fuel well **19**. With the utilization of full-range gasoline (and corresponding increases in manifold pressure), the elution zone of the forward section **27***a* as well as the vapor zones within the fuel well **19** and gas tank **23** can be placed in fluid contact with the carburetor **13** by operation of exhaust start valve **25***b* and evaporative control valve **25***c*. The elution zone can be connected via conduits **36, 88***a* and **88***b* (connected to respective ports of valve **25***b* of FIG. **9**) to the carburetor **13**; the fuel well **19** via conduit **83** and valve **25***c* can be also placed in fluid contact with the conduits **88***a* and **88***b*, as can the gas tank **24** via conduit **84** and valve **25***c*. The elution zone of rear section **27***b* is always in fluid contact with the carburetor **13** via the air intake system **12**. In that way, as desorbtion of the adsorbed compounds occurs, say, as warmed gases are conveyed in heat transfer contact with the elution zones, and the compounds are swept into the carburetor **13**, there can be a simultaneous conveyance of evaporative emissions if any, from fuel well **19** and gas tank **24**. With the desorption of the heavier compounds within the first and second elution zones it should also be pointed out that vapors captured within the adjacent adsorptive capture zone of the cannister assembly can likewise be purged. The captured evaporative emissions pass directly into the air intake system **12** and thence to the carburetor **13**, in the manner of desorbed materials from the elution zone of the rear section **27***b*.

In FIG. **5**, the conveyance of the hot exhaust gases from the exhaust manifold is under control of additional electrical circuitry (not shown) of the controller circuit **26**. When the temperature of the exhaust manifold reaches a selected temperature, a relay (not shown) is tripped to pass the purging gases through the cannister assembly **27** via conduit **64**. The desorbed materials within the elution and vapor adsorption zones of the cannister assembly **27** are ultimately consumed within the combustion chambers of the engine.

Where the aromatic compounds within the elution zone of the cannister assembly **27** have relatively high boiling points, too high in fact to be renewed by passing adjacent engine air in heat transfer contact with the elution zone, the embodiment depicted in FIG. **5** is especially useful. In this regard, the adsorbent material **56** and **56'** of FIG. **5** can be simultaneously renewed using the hot exhaust gases as the purging agent. If the temperature of such exhaust gases range from 700° F to about 800° F only a relatively short desorption time is required. Temperatures of the adsorbent beds comprising the elution zones can be a range from 400°–500° F with about 450° F being a satisfactory operating temperature.

Generally desorption time is quite short for such range setting, say being from about 2–12 minutes in duration. The resulting desorbed high molecular weight compounds then pass through the air intake system and carburetor **13** to the combustion chambers where they are consumed.

Capture of evaporative emissions within vapor adsorption zones of the cannister assemblies **27** of FIGS. **2** and **5** can also be desorbed utilizing the purging gases in the manner described above. It should be noted that the captured adsorbates within the vapor capture zone are mostly light low molecular weight constituents. According, the adsorbent material indicated at **45** in FIG. **2** and at **62** in FIG. **66** should be nonpolar. In this regard, the following non-polar adsorbent materials are preferred in carrying out this aspect of the present invention.

Non-Polar Adsorbent Material	Remarks
Charcoal	
Charcoal blacks	
Graphite	
Resins and Plastics	Organic only
Paraffins	
Stibnite	
Sulfides	Metallic only
Talc	

FIG. **8** illustrates yet another mode for desorbing the elution and vapor adsorption zones of the cannister assembly of FIGS. **2** and **5**. In accordance with the illustrated embodiment, engine air is heated by passing the air adjacent to exhaust manifold **70** and thence through the cannister assembly where desorption occurs.

In more detail, the exhaust manifold **70** is provided with an exterior hood **71** having lower skirts **72** which snuggly fit adjacent to the exhaust manifold, yet are open to incoming air. A central register **73** is also provided with a nozzle **74**. Nozzle **74** in turn is attached by flexible conduit **75** connected at a port **76** say at the air intake line **16***a* of the air intake system of the embodiment of FIG. **2**. At the air intake line **16***a*, a solenoid operator **77** is positioned so that it is damper **78** is in register with port **76**. Opening the damper **78** allows warmed engine air to enter the cannister assembly (not shown).

SEQUENCE OF OPERATIONS.

Reference should now be had to the Figures illustrating the method aspects of the present invention. In more detail, it should be apparent that the initiation of the cold start cycle automatically occurs when the driver closes ignition switch **26***c* of the controller circuit **26** of FIGS. **1** and **5**. Before the driver engages the ignition switch **26***c*, however, the valve and conduit network **25** and particularly the evaporative control valve **25***c* is in the position illustrated in FIG. **10** to carry out the vapor adsorption control function of the present invention. That is to say, the evaporative **3**-way control valve **25***c* is in a relaxed state so that its exhaust port **80** and inlet ports **81** and **82** are in fluid communication with fuel well **19** of the carburetor **13**, and to the gas tank **23**, respectively, say via conduits **83** and **84**. When the engine is in an inactive state, and evaporation of the fuel occurs, the vapors pass through conduits **83** and **84**, **3**-way control valve **25***c* and conduit **38** to the vapor adsorption zone of the cannister assembly **27** of FIGS. **2** and **5**. Adsorption of the vapor prevents its escape into the atmosphere.

Prior to initiation of cold start, assume the fuel well **19** has been emptied of full-range fuel. In this regard, consider also the function of drain conduit **85** of FIGS. **1** and **5** connected between fuel well **19** and gas tank **23**. When the engine is in an inactive state, fuel within the fuel well **19** (liquid phase) drains therefrom via conduit **85** to the gas tank **23**. As shown, the conduit **85** is provided with an oriface **86** so as to control the rate of drainage of the fuel, say at a rate which will allow total removal of all fuel from the well within a 6–12 hour period. Thus, when the engine is parked overnight, the drain conduit **85** in cooperation with oriface **86** provide for total removal of full range fuel from the fuel well **19**. It should also be apparent that if the drainage conduit **85** is mounted at the side-wall of the fuel well (not at the bottom wall as shown) not all of the full range fuel will be drained. Instead, a residual reservoir remains, the amount of which is a function of the connector position relative to the top wall of the fuel well, e.g., if the connector to the fuel well and conduit is at a location say about two-thirds of the way away from the top wall, the residual fuel would be one-third of the total fuel well capacity. During initial starting of the engine, the position of nozzle **20** of the carburetor **13** could be arranged, depthwise, so that a selected, compatible mixture of the residual and eluted fuel would enter the carburetor to effect cold start of the engine.

Furthermore, it should also be apparent that the positions of the drain conduit **85** and fuel well **19** can be arranged such that the cold start fuel contribution provided by fuel well **19** can be essentially eliminated. Under such circumstances, the cannister assembly **27** is modified so that only rear section **27***b* is operative. That is, forward section **27***a* is eliminated from the cold start operation. Instead, the full-range fuel previously passing thereto is instead conveyed directly to the fuel well **19**. But the positions of the nozzle **20** and fuel well **19** are arranged during the normal starting period such that little, of any, full-range fuel flows from the fuel well **19** via nozzle **20** into the carburetor **13**.

As the engine turns over, the fuel pump **24** conveys full-range fuel through inlet start valve **25***a* to the cannister assembly **27** of FIGS. **2** or **5**. Within the cannister assembly **27**, the full-range fuel percolates simultaneously through the first and second elution zones culminating in the elution of low molecular weight components at fuel well **19** and at air intake assembly **12**, respectively. High molecular weight components of the full-range fuel remain absorbed. A metered amount of the light components is conveyed through the carburetor **13** into the intake manifold **11** and thence to the combustion chambers of the engine. After selected rise in the engine temperature, as measured by bimetal switch **26***b* of the controller circuit **26** say positioned at the water jacket or exhaust manifold of the engine, control relay **26***a* becomes deactivated, resulting in the cold start inlet and exhaust valves **25***a* and **25***b* returning to relaxed positions as shown in FIG. **9**. The fuel system thus switches over to full-range fuel, such fuel passing from fuel pump **24** via conduit **87***a* to inlet valve **25***a* and thence from U-shaped conduit **87***b* and exhaust valve **25***b* to the fuel well **19**. As full-range fuel is utilized, the elution zones of the forward section of the cannister assembly followed by the rear section are placed in fluid contact with the carburetor.

It should be pointed out that during the operation of the engine, the evaporative control valve **25***c* of the valve and conduit network **25** remains an activated state as depicted in FIGS. **1**, **5**, and **9**. However, when the driver opens the ignition switch **26***c* of the controller circuit **26**, the evaporative control valve **25***c* is likewise deactivated which places it in the position depicted in FIG. **10** whereby the vapor adsorption zone of the forward section **27***a* of the cannister assembly **27** is in direct fluid contact with the fuel well **19** and gasoline tank **23**. In that way, as evaporative emissions are formed within the fuel well **19** or the gasoline tank **23**, they are conveyed via conduits **83** and **84** respectively through inlet ports **81** and **82**, exhaust port **80** and conduit **38** to the vapor adsorption zone.

While certain preferred embodiments of the invention have been specifically disclosed above, it should be understood that the invention is not limited thereto as many variations will be readily apparent to those skilled in the art and thus the invention is to be given the broadest possible interpretation within the terms of the following claims.

We claim:

1. In a spark-ignition internal combustion engine of the type having an air intake system, a fuel intake system, and a carburetor means interconnected therebetween for mixing of full-range fuel with air to form a combustible mixture for delivery to combustion chambers of said engine, the improvement for reducing exhaust pollutants of said engine by dynamically varying the composition of said full-range fuel during cold starting of said engine (cold start cycle), comprising;

i. two-stage cannister means selectively connectable between said carburetor and a reservoir of said full-range fuel and including separate first and second adsorption beds of adsorbent material each in flow arrangement with said reservoir means whereby said full-range fuel dynamically percolates thereover during said cold starting of said engine to elute first and second cold start fuel streams,

ii. said first stream being an atomized spray composed essentially of low molecular weight constituents and being carried into said carburetor by intake air of said air intake system,

iii. said second stream being composed essentially of low molecular weight liquid constituents and being conveyed under pressure to a fuel well of said carburetor, said first and second streams being mixed together along with air by said carburetor to form a highly combustible cold start mixture for delivery to said combustion chambers of said engine,

iv. control means including flow condition means for controlling flow of said fuel including said cold start fuel streams between said reservoir means, said cannister means and said carburetor as a function of at least one of several engine operating parameters to assure at least substantially simultaneous delivery of said cold start fuel streams to said carburetor during cold starting of said engine.

2. The improvement of claim **1** in which said flow condition means of said control means is further characterized by a first active state initiated by occurrence of a selected engine parameter indicative of the start of said cold start cycle whereby said full-range fuel is allowed to flow in parallel from said reservoir means to each of said adsorbent beds in said cannister means to initiate elution of said first and second cold start fuel streams and whereby said first and second cold start fuel streams are allowed to flow in parallel from said cannister means to said carburetor to form said highly combustible cold start fuel-air mixture.

3. The improvement of claim **2** in which said absorbent materials comprising said first and second adsorbent beds are selected on a basis of providing efficient retardation of high molecular weight constituents of said full-range fuel percolating therethrough so that essentially only low molecular weight constituents are eluted from each of said beds of said cannister means during cold starting of said engine.

4. The improvement of claim **3** in which said adsorbent material is selected from the group consisting of silica gel, alumina, barium sulfate, calcium carbonate, glass, resins and plastics, quartz, titanium dioxide, metallic oxides and zeolites, adapted for use in liquid-liquid partition chromatography.

5. Apparatus for reducing exhaust and inoperative pollutants produced by a spark-ignition internal combustion engine of the type including an air intake system, fuel intake system, and a carburetor interconnected therebetween for mixing full-range fuel with air to form a combustible mixture for delivery to combustion chambers of said engine, comprising:

i. a two-stage cannister assembly including first and second sections each containing a bed of adsorbent material capable of selectively eluting at cold start first and second parallel cold start fuel streams each composed essentially of only low molecular weight constituents, said first stream being composed of low molecular weight liquid constituents conveyed to a fuel well of said carburetor said second stream being an atomized spray carried into said carburetor by intake air of said air intake systems, said first and second streams being mixed together with air by said carburetor, said first section also including another bed of adsorbent material capable of selectively absorbing vapor constituents of said full-range fuel during an inoperative state of said engine,

ii. valve and conduit network means attached between said cannister assembly, a reservoir means for said full-range fuel and said carburetor for providing selective flow of said fuel including said cold start fuel between said cannister assembly, said reservoir means and said carburetor, said network means including a first plurality of conduit and valve means including first and second valve means controlling parallel flow relative to each of said sections of said cannister assembly so as to allow, (a) in a first operating state flow of said full-range fuel from said reservoir means to said each section and flow of said first cold start fuel stream from said cannister assembly to said carburetor to provide for rapid starting of said engine without producing excessive exhaust pollutants and (b) in a second operating state, full-range fuel to flow from said reservoir means to said carburetor bypassing said cannister assembly after said engine is in a normal running condition, said network means also including a second plurality of conduit means including a third valve means operatively connected between said another bed of said first section of said cannister assembly said fuel reservoir means and said carburetor for selectively conveying vapor emissions of said fuel within said fuel reservoir and/or said carburetor to said another bed when said engine is in said inoperative state,

iii. control means operatively connected to said first, second and third valve means of said valve and conduit network for changing operation states so as to direct fuel flow relative to said cannister assembly, said reservoir and carburetor as a function of one or more engine operating parameters.

6. Apparatus of claim **5** in which said carburetor includes a fuel well and a bore each in selective contact with said first and second sections of said cannister assembly and said reservoir means through said first plurality of conduit means including said first and second valve means, said first valve means being positioned between said reservoir means and a parallel inlet of each of said sections of said cannister assembly and having first and second operating states for controlling flow of full-range fuel between said reservoir means relative to each of said section and said second valve means, said second valve means being positioned between said fuel well and an outlet of said first section and also having first and second operating states coextensive in time with said operating state of said first valve means for controlling flow of said full-range fuel and said cold start fuel stream from said first sections relative to said fuel well as a function of engine temperature.

7. The apparatus of claim **6** in which said fuel well and said reservoir means are placed in selective vapor contact with said another bed of said first section through said second plurality of conduit means including said third valve means as a function of a selective engine parameter indicative of said inoperative state in said engine whereby evaporative vapor emissions from said full-range fuel within said fuel well and said reservoir means can be conveyed to said another bed of said first section for adsorption therein thereby preventing escape into atmosphere surrounding said engine.

8. Apparatus of claim **7** in which said first and second adsorbent beds are formed of a polar adsorbent material while said another adsorbent bed is formed of a nonpolar adsorbent material.

9. Apparatus of claim **6** in which said first section includes an elongated tubular means disposed within a forward section of a shell housing while said second section is disposed within a rear section of said shell housing with air intake control means connected to a source of heated gas, so as to allow selective flow of said heated gas through said first and second sections for purging both said first, second and another bed of adsorbed fuel constituents, said purged constituents being carried into and consumed within said combustion chambers of said engine.

10. Apparatus of claim **9** in which said air intake system includes an air cleaner assembly having an air intake line and an air filter, said air intake line including support means for rigidly supporting said cannister assembly in flow relationship with a bore of said carburetor.

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